

A SOFT LITHOGRAPHIC PROCESS FOR FABRICATING INTEGRATED ITO ELECTRODE-LIQUID CRYSTAL ALIGNMENT LAYERS

RELATED APPLICATIONS

This application claims the benefit of priority under 35 U.S.C. § 119(e) from United States Provisional Application Serial Number 60/426,160 filed November 14, 2002, entitled "Self-Aligned Structures and Method of Making Same" and United States Provisional Application Serial Number 60/427,738 filed November 20, 2002, entitled "A Soft Lithographic Process for Fabricating Integrated ITO Electrode Liquid Crystal Alignment Layers", which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to systems and methods to self-aligning structural layers that may be used in electronic display elements. More specifically, the present invention relates to systems and methods for self-aligning electrodes that may be used for color filters in electronic display elements.

BACKGROUND OF THE INVENTION

Liquid crystal displays (LCDs) use nematic liquid crystals sandwiched between glass plates to modulate light transmission through the display. When an electric field is applied to the liquid crystal layer by transparent ITO electrodes, the LC molecules, which are elongated in shape, align themselves parallel to the applied field and normal to the glass plates. In this state, polarized light travels through the LC layer without having its polarization state rotated. Because the LC module is placed between crossed polarizers, the display appears dark. In order

for displays to allow light through when the applied field is off, the liquid crystal director on opposite sides of the glass chamber must be oriented 90° with respect to each other. In this situation, the polarization state of the light is rotated by 90° and exits parallel to the analyzer, thus making the display appear light. The orientation of the LC director at the surface of each glass plate is controlled by a so-called rubbing layer which is typically a polyimide layer that has undergone successive mechanical rubbing steps to create alignment of the polymer chains and mechanical grooving of the surface. This surface treatment induces the LCs to align parallel to the rubbing direction. In the current LCD manufacturing process, separate layers are used for the transparent ITO electrodes and the polyimide rubbing layers.

Figure 1, generally at 100 shows a conventional passive matrix display. The conventional display in Figure 1 includes a front plate and a back plate. The front plate includes glass plate 108 with a polarizing filter 110 at its exterior surface. Color filters 112, 114, and 116, red, green, and blue, respectively, are disposed on interior surface of the glass plate. The color filters 112, 114, and 116 are disposed adjacent one another. The filters are covered by transparent plate 118. Spaced apart transparent electrode 120 of ITO disposed on the plate. These electrodes precisely overlay the color filters. Interior to transparent electrodes 120 is liquid crystal alignment layer.

The back plate consists of glass plate 102 that has polarizing filter 104 disposed at its exterior surface. The interior surface of glass plate 102 has spaced apart transparent electrodes 106 made from ITO disposed there. These electrodes are disposed perpendicular to electrodes 120 of the front plate. Interior of transparent electrodes 106 is alignment layer 107.

The two alignment layers are spaced apart by a spacer 124. Liquid crystals are disposed on the spacer between the alignment layers.

There needs to be easy and efficient method to align the electrodes with the color filters.

SUMMARY OF THE INVENTION

The present invention is directed to systems and methods for self-aligning electrodes for color filters of passive matrix displays. The present invention includes forming the front plate of a display by molding matrix lines on a substrate. These form black matrix lines. The black matrix lines define the boundaries for the red, green, and blue color filters. The black matrix lines block the transmission of light between pixels.

Next, the red, green, and blue color filters are molded onto the substrate in the red, green, and blue color areas defined by the black matrix lines. The color filters extend above the black matrix lines. Following the disposition of the color filters, an ITO layer is deposited on top of the color filter and black matrix lines. The ITO will be used to form the transparent electrodes.

A flat stamp coated with etch-resist is contacted with the ITO. This will coat the ITO on the color filters with etch-resist but not the ITO covering the black matrix lines.

Following the coating of the ITO covering the color filters, the structure is etched to remove the ITO in the recesses over the black matrix lines. This will define electrically isolated self-aligned pixel electrode lines on the color filters.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a cross-sectional view of prior art passive matrix display.

Figure 2 shows a method for fabricating a passive matrix display front plate.

Figure 3 shows a method for fabricating a passive matrix display back plate.

Figure 4 shows a cross-sectional view of a passive matrix display according to the present invention.

Figure 5 shows a method of the present invention by which grayscale may be achieved in a passive matrix display by using a group of electrodes of differing area.

Figure 6 shows a system for fabricating the front plate according to the present invention.

Figure 7 shows a system for fabricating the back plate according to the present invention.

Figure 8 shows a method for forming of the color filters.

Figure 9 shows a method of using soft lithography to pattern liquid crystal alignment layers into ITO electrode.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is a method for self-aligning transparent electrodes and color filters of passive matrix displays. The present invention also includes systems for forming self-aligned transparent electrodes and color filters. Further, according to the present invention, surface chemistry and contact printing are used in combination with surface topology to create self-aligned electrodes. This results in significant efficiency in forming passive matrix displays.

Referring to Figure 2, generally at 200, a method for forming front plate of a passive matrix display will be described. Now referring to Figure 2, glass substrate 202 has lines 204 of a light blocking material disposed the length of the display to form a predetermined percentage, preferably one-half, of the “black matrix”. The black matrix lines 204 define the boundaries of the individual red, green and blue color filter areas and function to block transmission of light between pixels in the inactive regions of the display.

In the next step of the method, red filters 206, green filters 208, and blue filters 210 are molded onto substrate 202 by conventional methods in the individual red, green and blue color areas defined by black matrix line 204. As is shown, the first two steps preferably alignment of the color filters and black matrix structures is achieved.

After the color filters are deposited on substrate 202 between black matrix lines 204 transparent conductor indium tin oxide (“ITO”) layer 220 is deposited on top of color filters and

black matrix lines 204. ITO is a standard material for pixel electrodes because of its properties. It is electrical conductive and transparent to visible light. Since the ITO deposition is conformal, the ITO atop color filters 206, 208, and 210 is raised with respect to the recessed black matrix lines 204. This surface topology is used to pattern ITO 220 into pixel address lines.

Flat stamp 230 (no features are required) coated with an etch-resist forming species that forms a self-assembled monolayer (or other surface modification that can serve as an etch resist) is contacted with the assembly. Because of the surface topology, the etch-resist is transferred at 240 only to ITO 220 aligned with color filters 206, 208, and 210, thus achieving self-alignment. Following this step, ITO 220 is etched (using, for example, aqueous hydrochloric acid) to remove material in the recessed areas over black matrix lines 204 to define electrically isolated, self-aligned pixel electrode lines 250. The surface layer (self-assembled monolayer or other surface modification species) can be removed if necessary or left in place. A system for carrying out the method described in Figure 2 will be described with respect to Figure 6.

In another embodiment of the method of the present invention, black matrix lines 204 and red, green and blue color filters 206, 208, and 210, respectively, can be molded directly onto the layer of polarizing film which may then be part of the display.

Referring to Figure 3, generally at 300, a method to fabricate a back plate of a passive matrix display will be described. Glass substrate 302 has ITO layer 304 deposited on it by conventional means. In an alternative embodiment, ITO layer 304 may be directly deposited onto a polarizing film that would be part of the display.

Stamp 306 having a patterned surface has a surface-modifying etch-resist forming species 308 disposed on it. Stamp 306 with the pattern of etch-resist is brought in contact with ITO 304 to microcontact print the pattern onto ITO 304. This transfers the pattern into ITO to define the

electrode lines for the back plate of the display. The ITO is etched which removes the ITO from the areas above when etch-resist was applied as shown at 310.

Finally, black matrix lines 312 are molded onto the substrate between the ITO addressing lines 314. The height of black matrix lines 312 is chosen such that when the front and back plates of the display are placed together, black matrix lines 212 serve to maintain an appropriate separation between the two plates.

A system for forming the back plate will be described with respect to Figure 7.

Referring to Figure 4, a cross sectional view of the passive display of the present invention is shown generally at 400. Back plate 402 of the display includes spaced-apart transparent ITO electrode lines 406 patterned directly onto the back of polarizing filter 404. However, it is understood that a glass substrate may be used as shown in the back plate formed according to Figure 3.

Front plate 410 includes color filter lines 412, 414, and 416 which are directed to the red, green, and blue filters, respectively, and patterned directly onto front polarizing filter 420. It is also understood that a glass substrate may be used as shown in the front plate formed according to Figure 2.

The passive matrix display at 400 includes spacers 434 to separate the front plate and back plate. The space between the plates contains liquid crystals 440. Transparent ITO electrode lines 430 are aligned onto color filters 412, 414, and 416. Finally, the electrodes 406 and 430 are LC aligned. While ITO is the standard electrode material for displays, modest electrical conductivity is a significant limitation in passive matrix displays where signals must traverse the entire display through ITO address lines. To achieve grayscale in a liquid crystal display, a range of voltages may be applied to obtain intermediate states of liquid crystal switching or a pulse

width modulation (“PWM”) approach may be employed to the same end. In either case, accurate grayscale in passive matrix displays is difficult due to the voltage drop and RC delays resulting from the resistance of ITO.

Passive matrix displays are often set up as simple black-and-white displays without grayscale, using a liquid crystal system with a steep response to voltage so that small voltage differences will effect complete switching. In this way, the voltage loss along an address line is tolerated and the display still switches fully between transmission and blocking of light. Significant voltage drops and RC delay generally make grayscale more difficult to implement in passive matrix displays.

Another aspect of the present invention is an approach to achieving grayscale that operates within the intrinsic nature of a passive matrix. The approach will be described referring to Figure 5. According to this approach, instead of using a single electrode line, multiple lines of different widths are employed so that each pixel may be switched on to varying fractions of the fully on or fully off states, i.e., grayscale.

As shown in Figure 5, each row address line enables a four-line address group, such as groups 502, 504, and 506. Although, a four-line group is selected, greater or less than a four-line group may be selected and still be within the scope of the present invention. Each line of a group has a different area so that grayscale may be achieved by using a group of electrodes. These electrodes can be turned on individually or in any combination to switch fractional pixel area. Grayscale may be achieved according to the following Table:

4-Bit Grayscale	
Binary:	Corresponding lines in the ON state:
0000	All OFF
0001	D
0010	C
0011	CD
0100	B
0101	BD
0110	BC
0111	BCD
1000	A
1001	AD
1010	AC
1011	ACD
1100	AB
1101	ABD
1110	ABC
1111	ABCD

According to the Table, one of sixteen levels ranging from a completely off to a fully on pixel is achieved by selection of the appropriate lines of a group. The widths shown for electrode lines A, B, C, D are illustrative only and represent an approximately linear increase in the

fraction of the pixel area that is switched with respect to progression through the 16 states of grayscale described at the bottom of the figure. Alternatively, a logarithmic dependence could be configured if desired.

Figure 6 generally at 600, shows a system for forming the self-alignment front plate according to the present invention. Feed reel 602 supplies flexible backing on to which is disposed the polarizing filter film 604. At the station including filter material dispense station 606, stamp/semi-cure drum 610, cure station 612, and inspection station 614. The red filter is molded on the polarized film. The mold face of drum 610 is shown at Figure 8. After the red filter is applied to the polarizing film, the green filler is molded onto the polarizing film by filler material dispense station 614, stamp/semi-cure drum 620, and cure station 622 and inspection station 624. Similarly, the blue filter is formed by filter material dispense station 626, stamp/semi-cure drum 630, cure station 632, and inspection station 634. After leaving inspection station 634, the front plate structure is wound onto take-up reel 636.

The front plate structure may also include the appropriate disposition of black matrix lines in the recesses between color filters which serve the purpose previously described.

Next, the face plate material from reel 636 is transferred to reel 650 or reel 636 is disposed at 650. ITO is then deposited over the surface of the color filter/polarizing film web 652. The ITO vacuum deposition system includes ITO disposition 654 and take-up reel 658.

The material on reel 658 is disposed at reel 660. Drum 664 has etch-resist deposited on its circumference at reservoir 668. This etch resist is placed on the raised surface of the color filters but not in the recessors between the filters. The etch resist coated structure is passed through etch both 672 then rinse 674. This will leave the ITO aligned with the color filters.

Next, the circumference of roller 680 will receive etch-resist from reservoir 682. The circumference is patterned for placing alignment ridges in the ITO by microcontact printing a pattern of fine lines of, for example, a self-assembled monolayer. Once this is done the web is passed through etch solution 686 and rinse 688 and inspect at inspection station 692. After, this is completed front plate is wound into take-up reel 694.

Referring to Figure 7, generally at 700, the process for forming the back plate will be described. Process for fabrication of the back plate/film of the invention. First, indium tin oxide is deposited onto one side of polarizing filter film. To pattern the electrode lines into the indium tin oxide, the web is passed into contact with a drum on which an elastomeric stamp has been affixed. The stamp has raised features in the pattern desired for the electrode lines. The stamp is inked with an agent that will form an etch block on the ITO, for example, an agent that will form a self-assembled monolayer, and transfers the agent to the ITO surface according to the pattern of the stamp. An etch and rinse are performed and the web inspected by in-line metrology. A liquid crystal alignment layer is patterned on the ITO electrode lines as described in Figure 8.

According to Figure 7, a polarizing film on flexible backing layer at 704 from reel 702 has ITO disposed on it by a vacuum disposition system that includes ITO dispenser 706. The film with ITO deposited on it is wound on to take-up reel 710.

The polarizing film with ITO disposed on it is disposed at reel 720. Next, etch-resist patterned on to the ITO. This is done by passing the web in contact with drum 724 on which an elastomeric stamp has been affixed. The stamp has raised features in the pattern desired for the electrode lines. The stamp is coated with etch-resist that will form an etch block on the ITO, for example an agent that will form a self-assembled monolayer, and transfers the agent to the ITO surface according to the pattern of the stamp. The coated ITO is then sent through etch both 730

and rinse 734. This results in the formation of the electrode lines. The web is inspected by at inspection station 736.

At drum 738, a liquid crystal (LC) alignment layer is patterned of the ITO electrodes. This is done by coating the patterned drum 738 and importing it to the ITO. The drum is coated with etch-resist from reservoir 740. The web is passed through etch both 744, then rinse 748. Following this, it is inspected at inspection station 750.

Finally at the station including spacer material dispense station 752, stamp/semi-cure roller 756 and cure station 758, spacers are formed on the back plate. This structure is inspected at inspection station 730 and wound to take up reel 752.

Referring to Figure 8, generally at 800, a method for forming the color filters is shown. These methods may be used in the process described in Figure 6.

Figure 9, generally at 900, shows a soft lithography process for fabricating integrated LC alignment layers. This involves patterning of LC alignment layers into ITO electrode lines. The same process applies to the front and back layers of the display. Elastomeric stamp 902A, 902B having raised features is used to microcontact print a pattern of a suitable etch resist (e.g. a self-assembled monolayer) onto the ITO electrodes 904A, 904B. Immersion of these assemblies into respective etch baths transfer the pattern of the etch-resist into the surface of the ITO layers.

In addition to the processing described above for fabricating ITO electrodes on the back plate, and the ITO electrodes that are self-registered to the color filter layer, it is understood that a similar process may be used to create a liquid crystal alignment layer on both the back plate and the color filter layer which is on the surface of the ITO layer.

The terms and expressions that are employed herein are terms of description and not of limitation. There is no intention in the use of such terms and expressions of excluding the

equivalents of the feature shown or described, or portions thereof, it being recognized that various modifications are possible within the scope of the invention as claimed.